Comparisons of AIRS Cloud Fields with CloudSat/CALIPSO

by

Brian H. Kahn[1], Moustafa T. Chahine[1], Robert E. Holz[2], Ralph E. Kuehn[3], Gerald G. Mace[4], Roger T. Marchand[5], Graeme L. Stephens[6], and Zhien Wang[7]

[1] Jet Propulsion Laboratory, California Institute of Technology, Pasadena, CA
[2] CIMSS/University of Wisconsin, Madison, WI
[3] NASA Langley Research Center, Hampton, VA
[4] Department of Meteorology, University of Utah, Salt Lake City, UT
[5] Pacific Northwest National Laboratory, Richland, WA
[6] Department of Atmospheric Science, Colorado State University, Fort Collins, CO
[7] Department of Atmospheric Science, University of Wyoming, Laramie, WY

AIRS Science Team Meeting
Pasadena, CA
March 29th, 2007

Motivation

- **Globally-coincident active/passive sensors on A-train**
  - Explore cross-platform sensitivities/capabilities
  - Previous validation efforts limited in scope
    - Surface point measurements, aircraft campaigns, etc.
    - Comparisons limited by temporal cloud evolution, sampling
  - Cloud type variations → Hartmann et al. (1992); Chen et al. (2000)
    - Which instruments can "do" certain cloud types?
- **Explore cloud sensitivity overlap of AIRS/CloudSat/CALIPSO**
  - Atmospheric Infrared Sounder (AIRS): IR sounder on EOS Aqua
  - CloudSat: Cloud radar ~ 55 sec behind Aqua
  - CALIPSO: Lidar ~ 69 sec behind Aqua
  - Analysis limited to cases when both instruments sense clouds
    - AIRS/CloudSat: ~52%
    - AIRS/CALIPSO TBD
- **Key question: does AIRS provide useful cloud fields?**
  - Is the vertical location "accurate"? What about as a f(cloud type)?
  - Talks at meeting reveal importance of accurate clouds fields

CloudSat/CALIPSO/AIRS data – 1

- **CloudSat GEOPROF and CLDCLASS products (R03)**
  - **GEOPROF locates cloud height/cloud confidence**
    - Range-resolved reflectivity profiles → cloud presence
    - Quality control: cloud mask confidence 0–40 (low–high)
    - Bin with cloud mask > 6 and > 10 (robust clouds ≥ 20)
  - **CLDCLASS partitions clouds into types**
    - Ac, As, Cb, Ci, Cu, Ns, Sc, St
    - Derived from cloud mask (GEOPROF), ECMWF T(z)
- **AIRS: up to 2 layers of effective cloud fraction (ECF) and cloud top pressure (CTP)**
  - Resolution: ECF ~ 15 km, CTP ~ 45 km:
  - ECF averaged to 45 km; CTP → CTH via AIRS T(z) retrievals
  - Methodology via cloud-clearing [e.g., Susskind et al., 2003, IEEE TGARS]
  - 324,000 retrievals/day (on 45 km FOV): compare 1/30 (CloudSat does not scan)

CloudSat/CALIPSO/AIRS data – 2

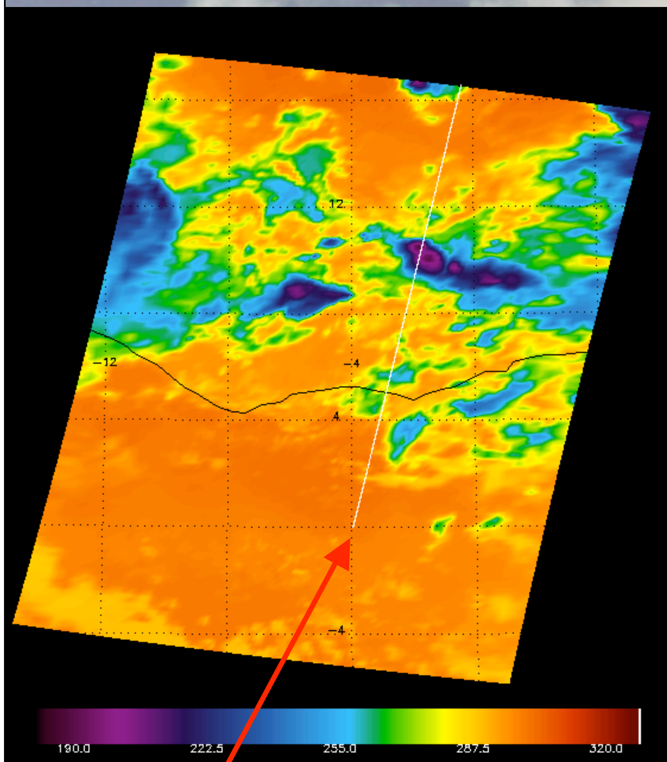
- **CALIPSO L1 total attenuated backscatter (532 nm) & L2 cloud/aerosol feature mask**
  - **Additional products available/in development**
    - 1064 nm backscatter, polarization, extinction, VIS/IR channels, cloud phase, cloud and aerosol type, optical depth, particle size, etc.
  - **L1 attenuated backscatter @ 532 nm**
    - Visualization of clouds/aerosols
    - Vertical resolution: 30 m (60 m) for surface–8.2 km (8.2–20.2 km)
    - Horizontal resolution: 333 m (1.0 km) for surface–8.2 km (8.2–20.2 km)
  - **L2 cloud/aerosol feature mask**
    - Cloud/aerosol discrimination released
    - Cloud/aerosol types to be released in future
    - Use feature top/base altitudes to locate cloud ~ up to 10 layers (8 for aerosol)
    - Horizontal averaging when cloud/aerosol tenuous
    - 60 m vertical resolution

Comparison Methodology

- **Use 4 days of comparison (07/22/06, 08/15/06, 09/08/06, 10/26/06)**
  - **Global statistics**
  - **Difference (separately) AIRS with CloudSat and CALIPSO cloud tops**
  - **2 reasons frequency vs. height PDFs not central to comparison**
    - Lose 1–1 cloud information: right PDF for wrong reasons
    - AIRS reports radiative Z_{CLD}, not cloud profiles (unlike CloudSat/CALIPSO)

- **Presentation material ordered as follows:**
  - **Example vertical x-sections of AIRS and CloudSat/CALIPSO cloud fields**
    - GEOPROF (AIRS V4 vs. V5)
    - CLDCLASS
    - CALIPSO 532 nm backscatter + cloud feature mask
  - **CloudSat – AIRS**
    - PDFs (All Clouds and individual cloud types)
    - Mean difference ± 1–σ variability
  - **CALIPSO – AIRS**
    - PDFs (All Clouds)
    - Mean difference ± 1–σ variability
  - **Summarize and conclude**

CloudSat X-section of tropical cloudiness



CloudSat track

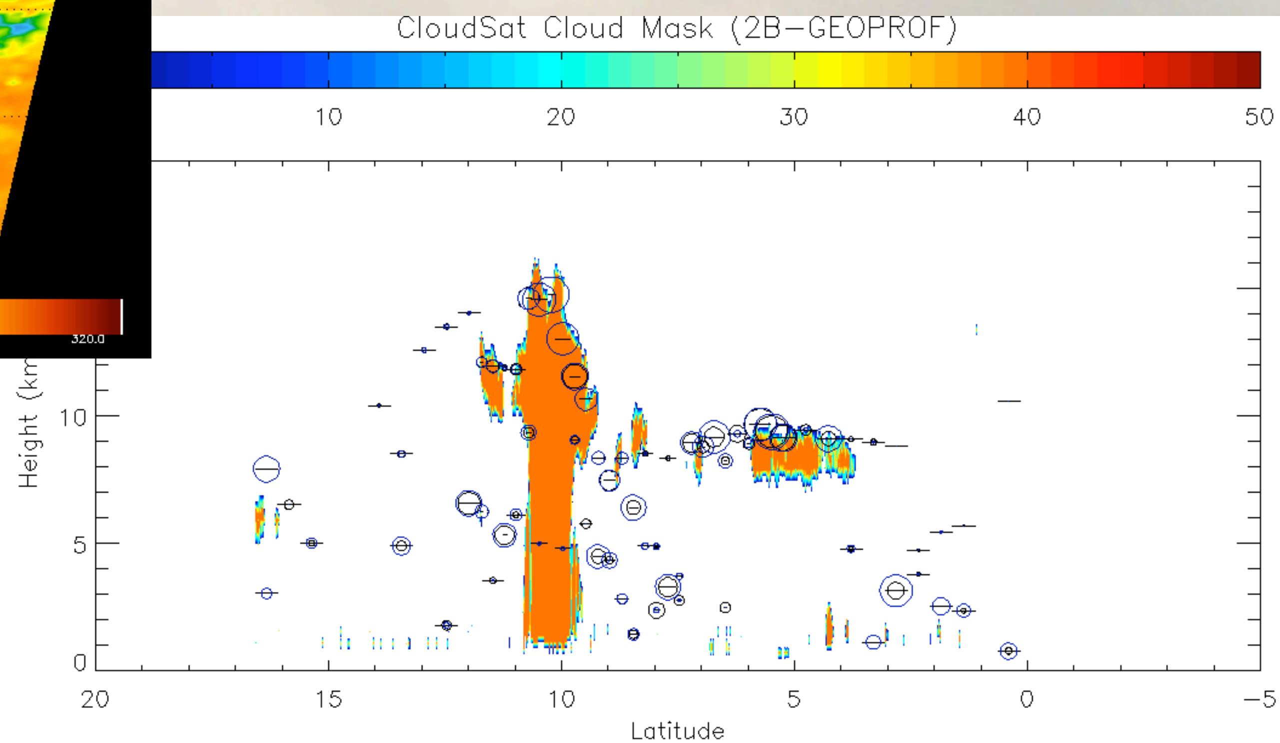
AIRS Cloud Height

AIRS Effective Cloud Fraction

Small

Large

AIRS Version 5 retrievals

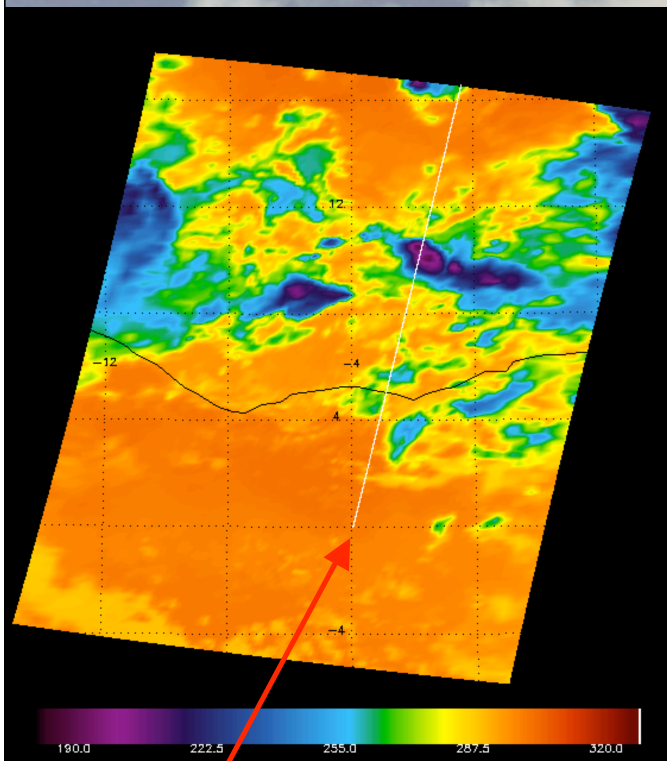


CloudSat X-section of tropical cloudiness

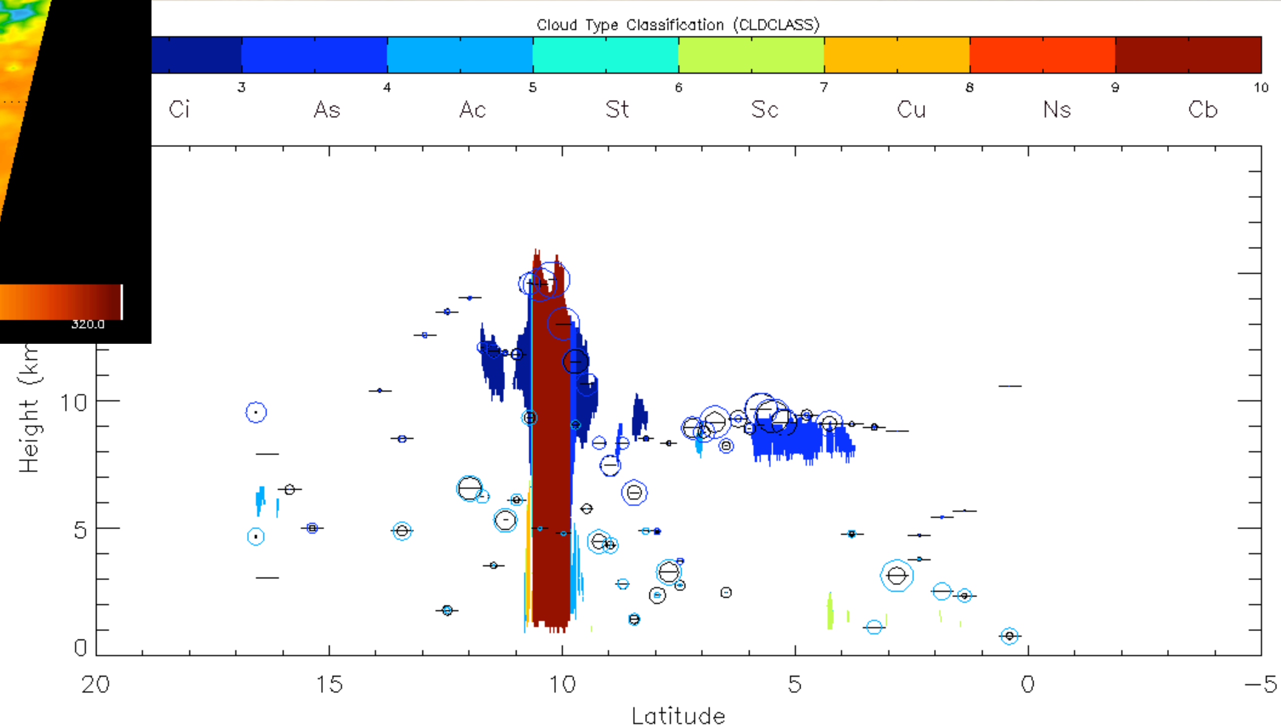
AIRS Cloud Height

AIRS Effective Cloud Fraction Small Large

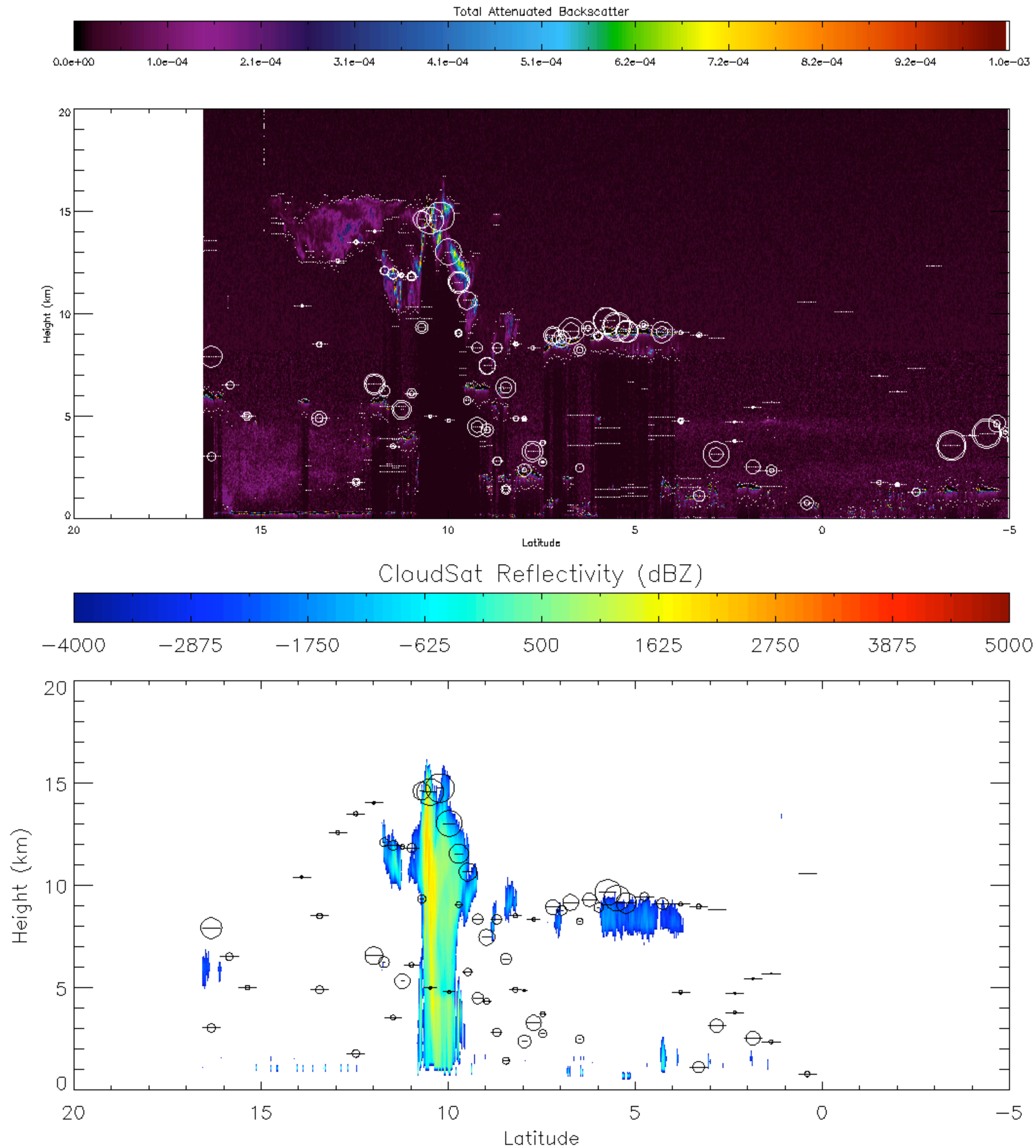
AIRS Version 5 retrievals



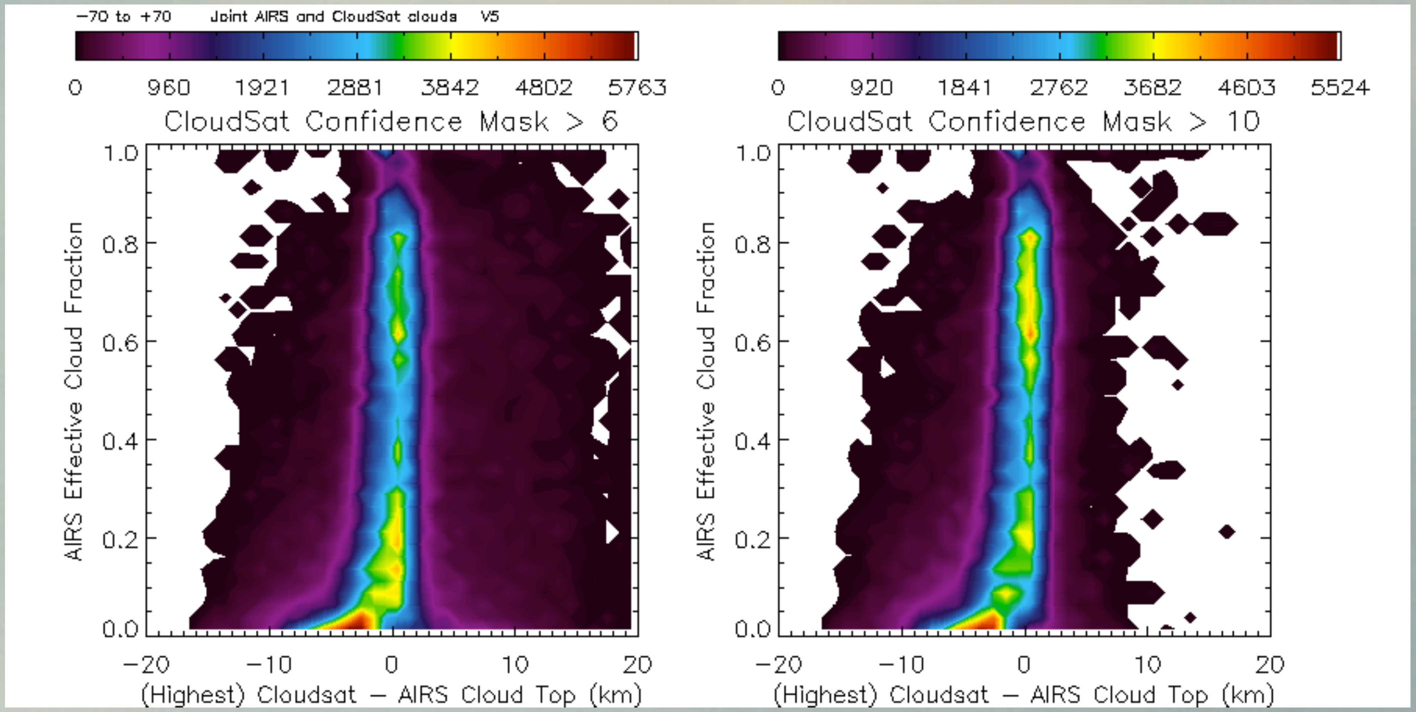
CloudSat track



CALIPSO + CloudSat X-section of tropical cloudiness



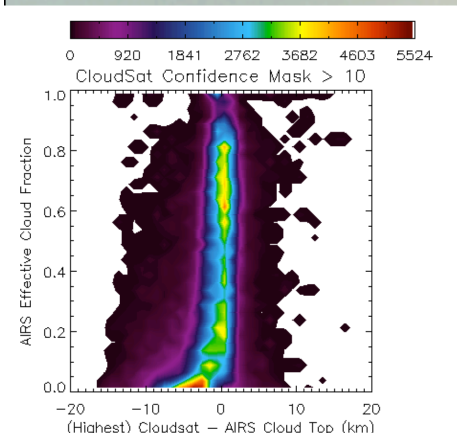
CloudSat – AIRS V5 (Upper Layer)



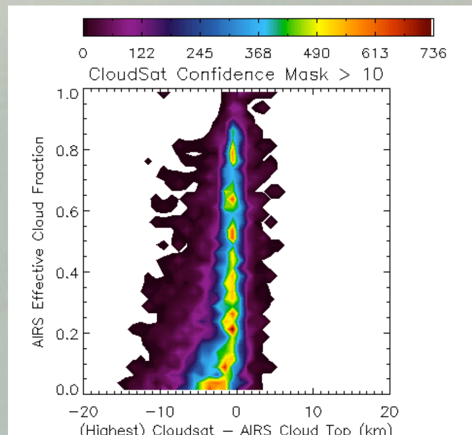
- CloudSat – AIRS for two cloud mask cut-offs (> 6 and > 10 on the left and right, respectively)
- Most points clustered near zero bias above ECF > 0.1
- More stringent cloud masking → less scatter
- ↓ in number of matched pairs with ↑ in ECF (more broken/transparent than opaque clouds)

CSat (> 10) – AIRS (Upper): Cld type PDFs

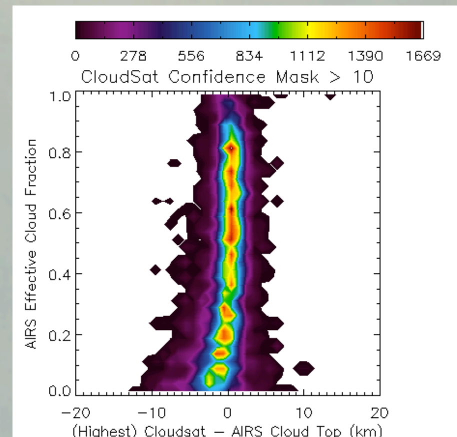
All Clouds



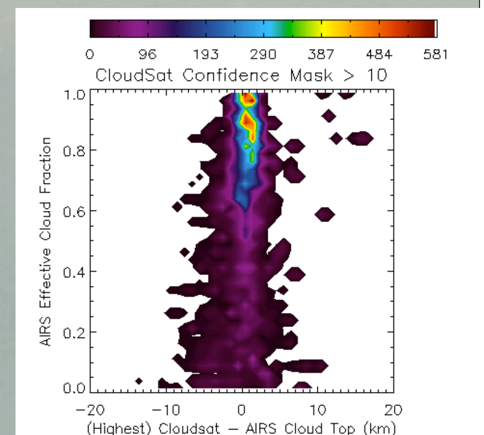
Ac



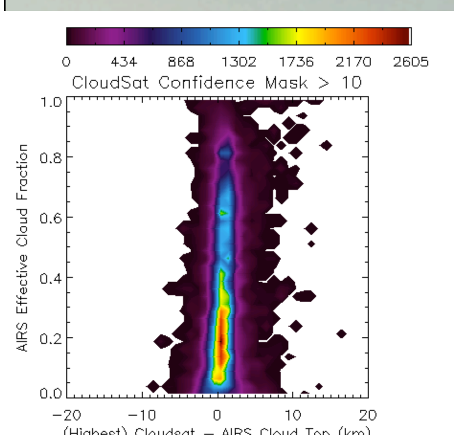
As



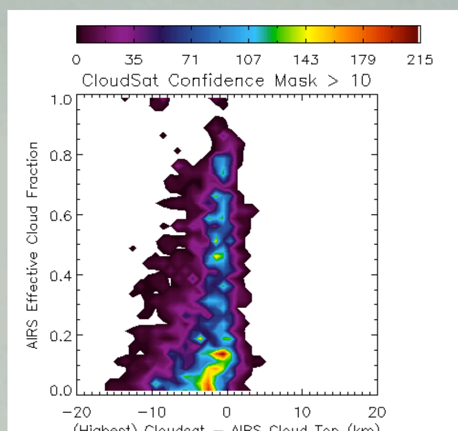
Cb



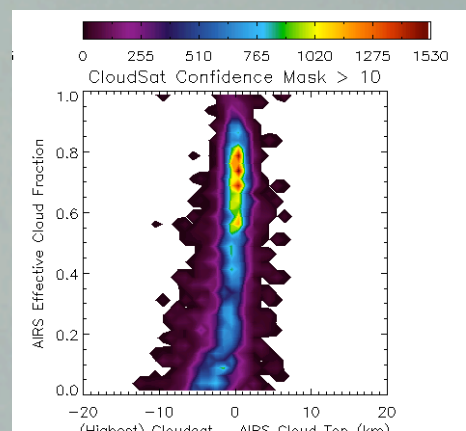
Ci



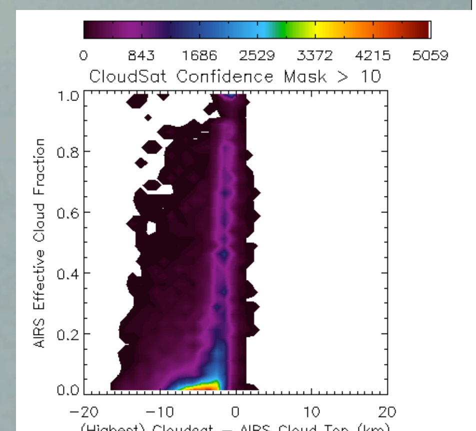
Cu



Ns



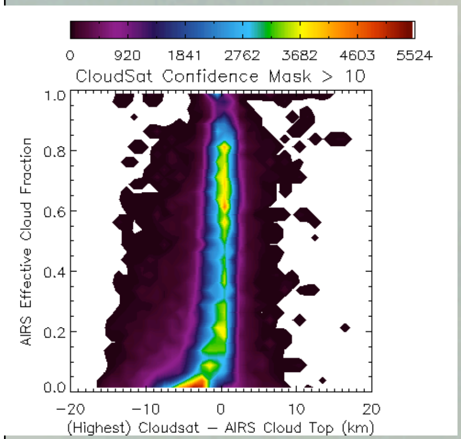
Sc



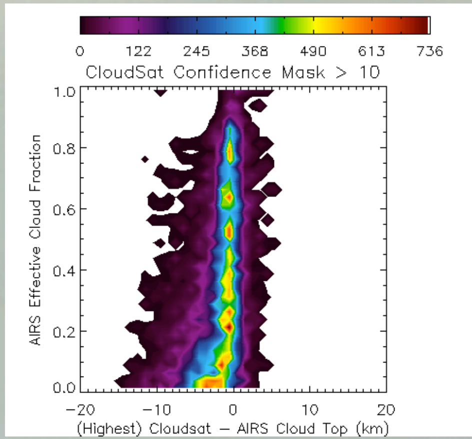
CSat (> 10) – AIRS (Upper): Cld type PDFs

More appropriate to compare Cu and Sc with AIRS lower layer

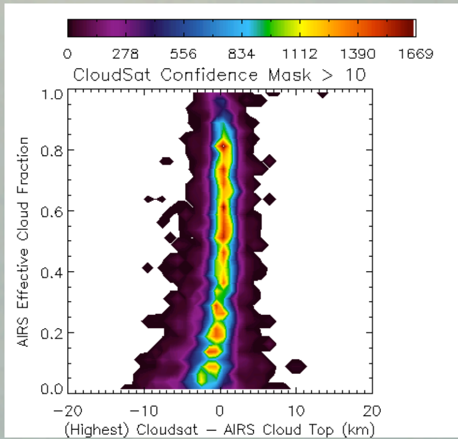
All Clouds



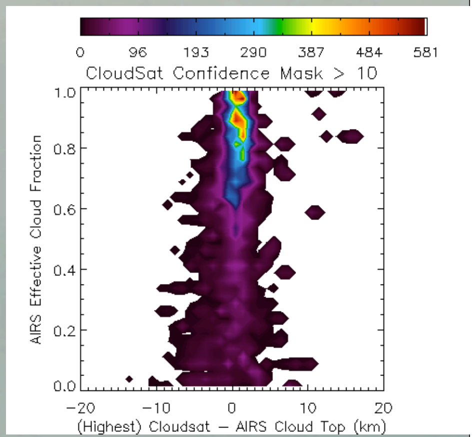
Ac



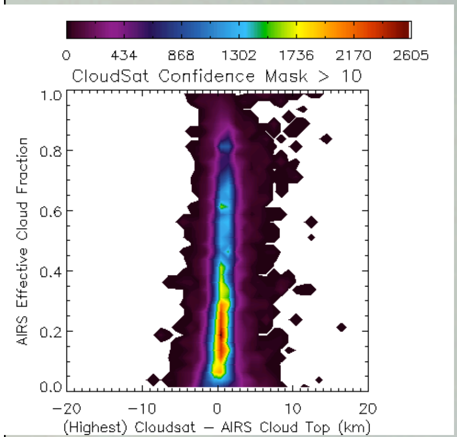
As



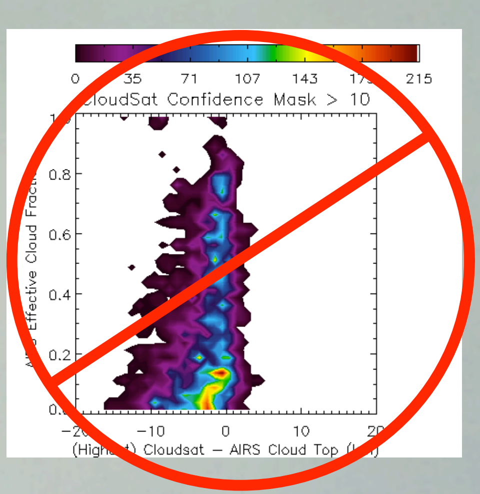
Cb



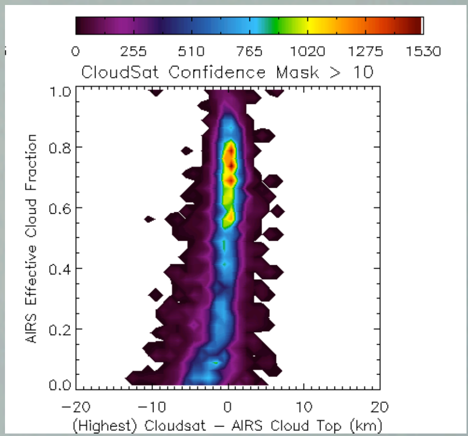
Ci



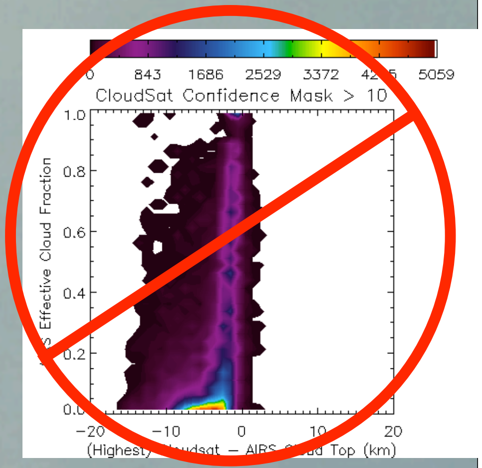
Cu



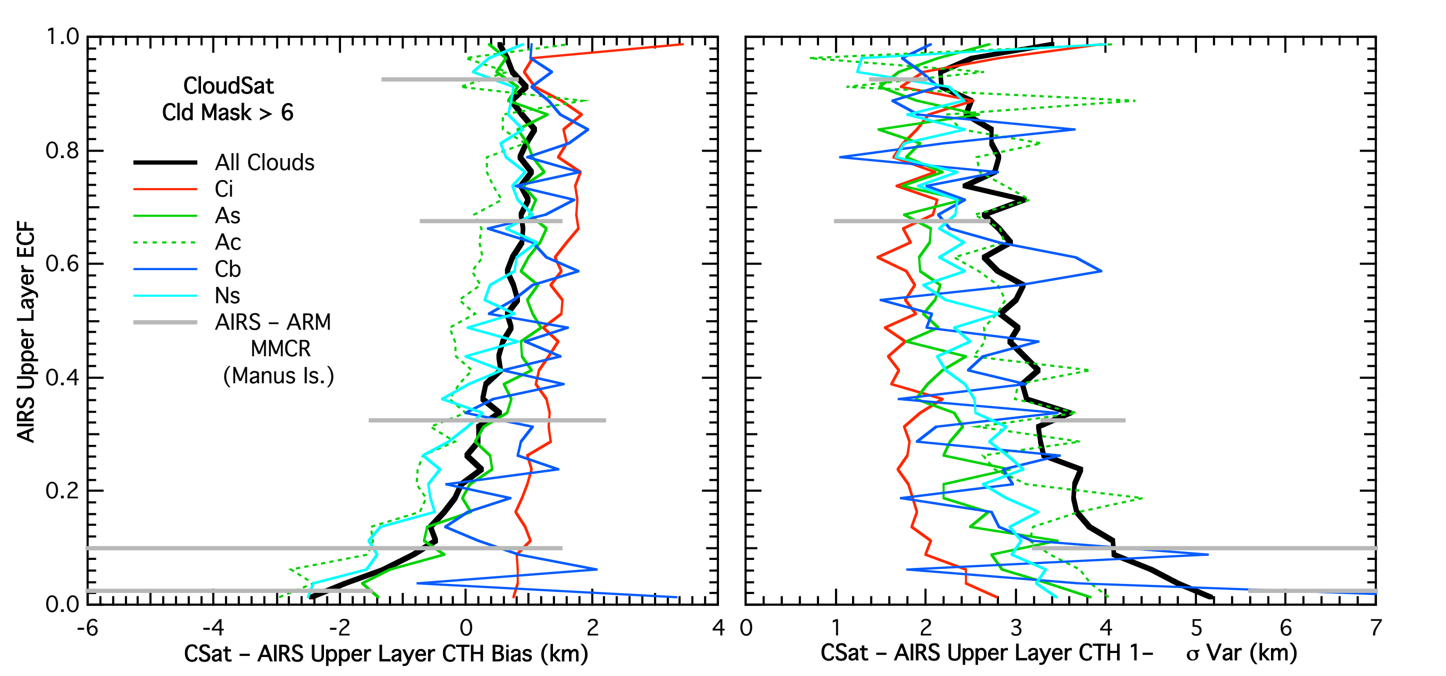
Ns



Sc

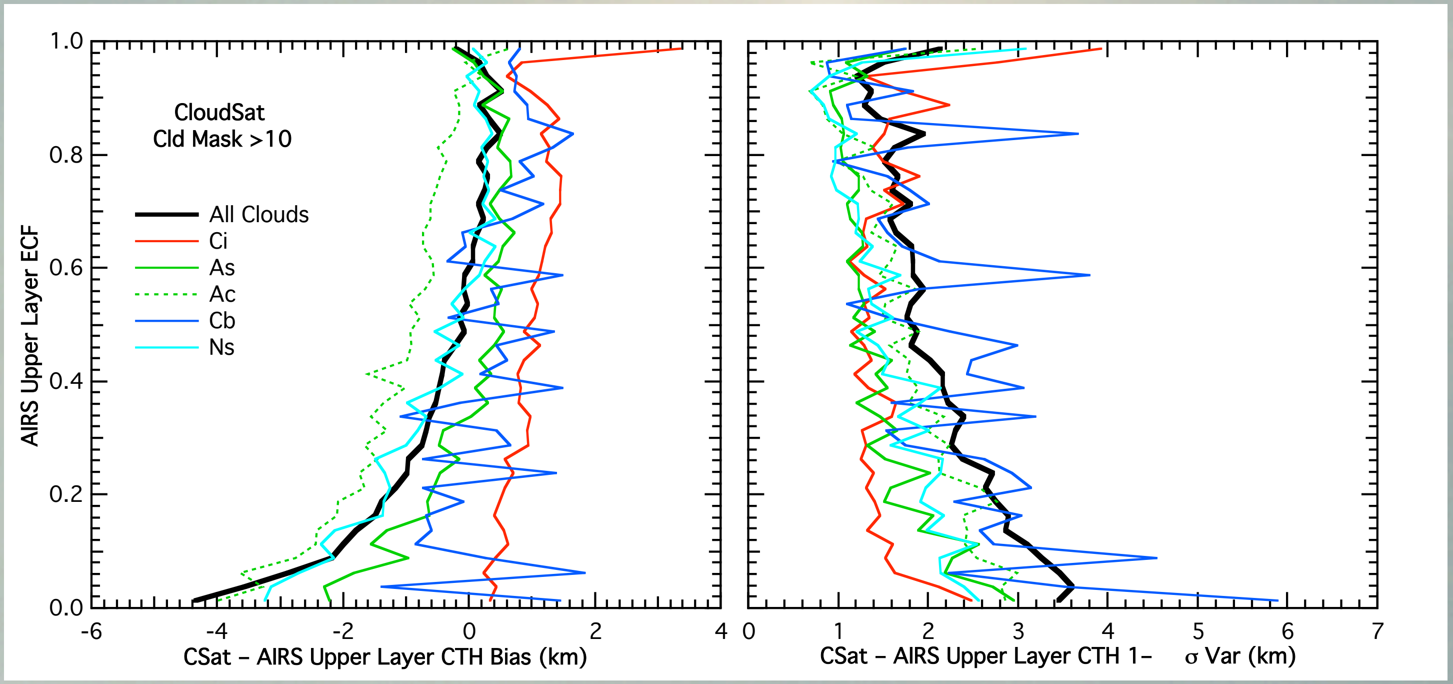


CloudSat (Mask > 6) – AIRS V5 (Upper Layer)



- Bias largest for ECF < 0.2, slowly varying for ECF > 0.2
- For individual cloud types (Ac, As, Cb, Ci, Ns) dependence of bias on ECF varies
- Variability for all cloud types larger than for individual cloud types (Ac, As, Cb, Ci, Ns)
- Manus Island surface-based ARM MMCR differences show larger bias, variability for ECF < 0.5, more similar at ECF > 0.5 [*Kahn et al.*, 2007, *J. Geophys. Res.*]

CloudSat (Mask > 10) – AIRS V5 (Upper Layer)

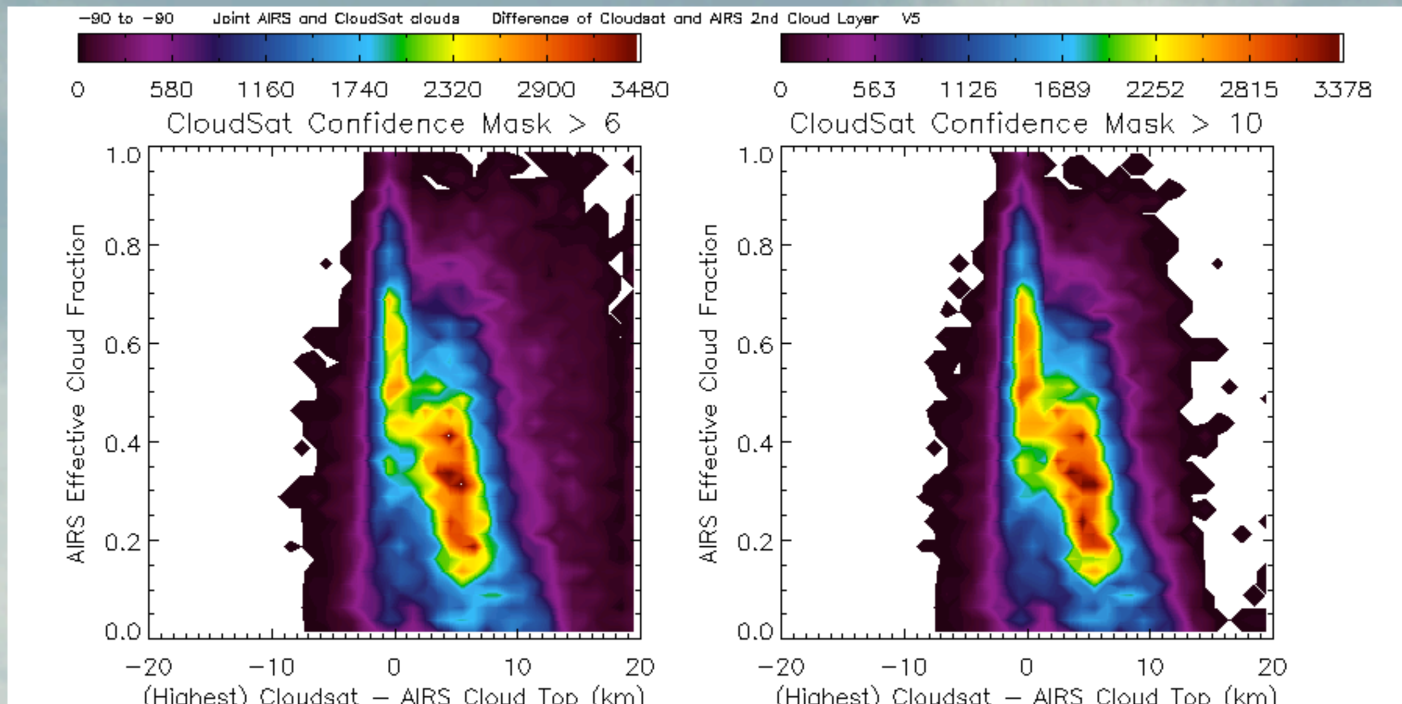


- For all clouds, bias shifts by 0.5–2.0 km (CloudSat lower), larger shift at lower ECF

- For individual types, bias shift more variable from type to type
  - Small for Cb and Ci; Ac larger than As

- Variability significantly reduced with more stringent cloud masking

CloudSat – AIRS V5 (Lower Layer)



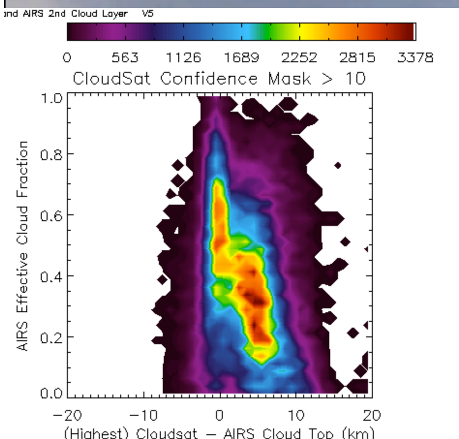
- CloudSat – AIRS for two cloud mask cut-offs (> 6 and > 10 on the left and right, respectively)
  - Lots more scatter when differencing with AIRS lower layer

- However, two “modes” of agreement:
  - Decrease in large differences with increasing ECF
  - Other “mode” centered along zero bias over range of ECF

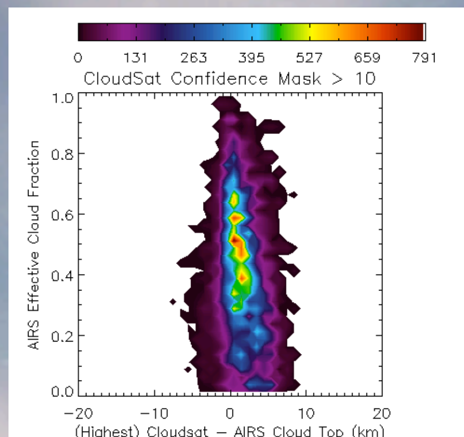
∴ AIRS shows skill for lower Cu/Sc layer: CSat misses thin Ci or erroneous AIRS upper layer

CSat (> 10) – AIRS (Lower): Cld type PDFs

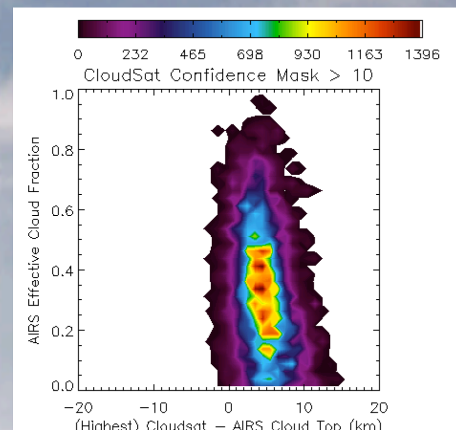
All Clouds



Ac

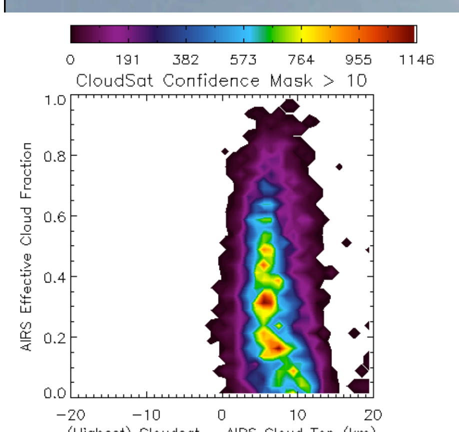


As

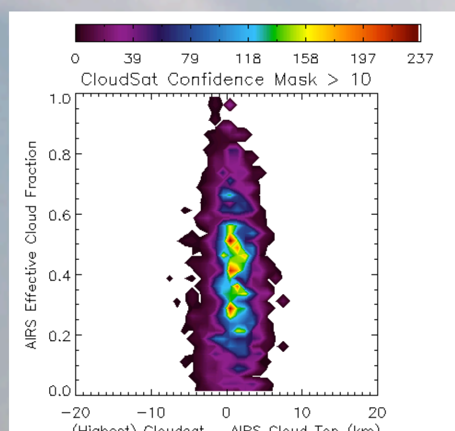


No Cb

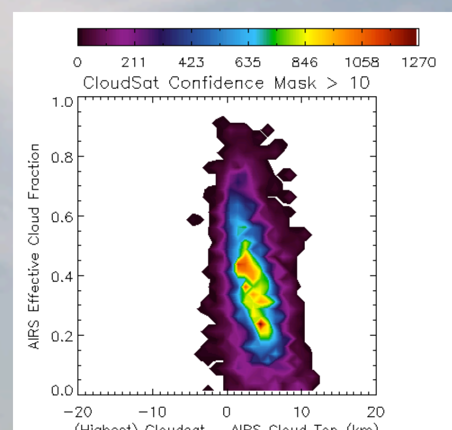
Ci



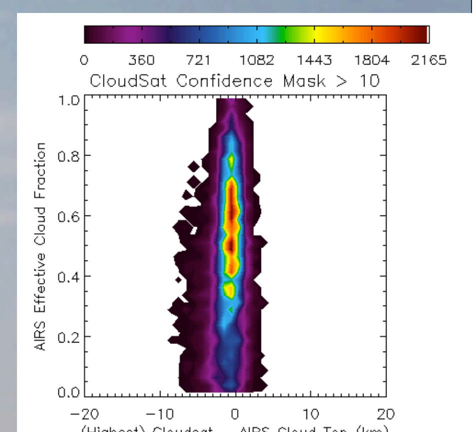
Cu



Ns

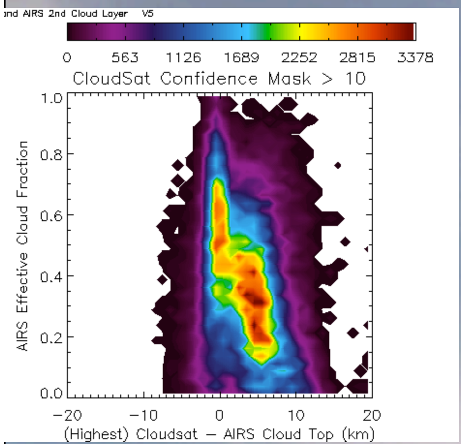


Sc

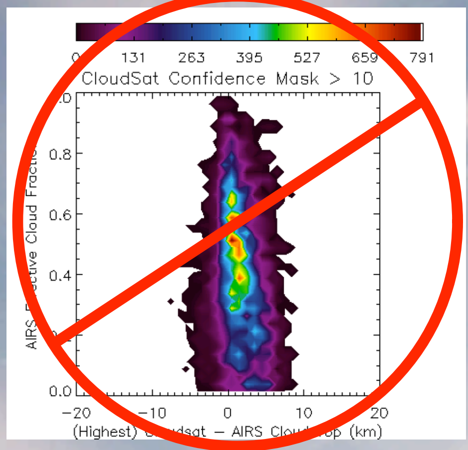


CSat (> 10) – AIRS (Lower): Cld type PDFs

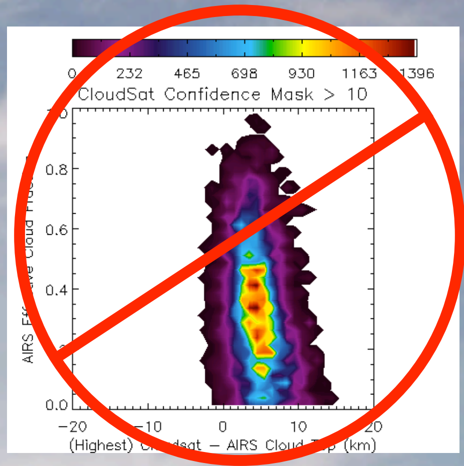
All Clouds



Ac

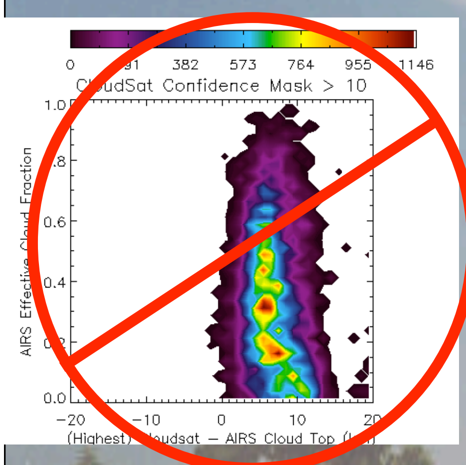


As

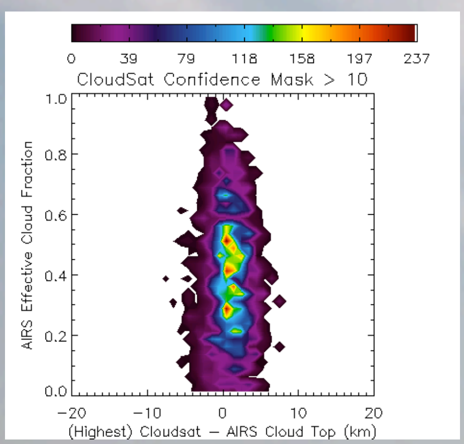


More appropriate to compare Ac, As, Ci and Ns with AIRS upper layer

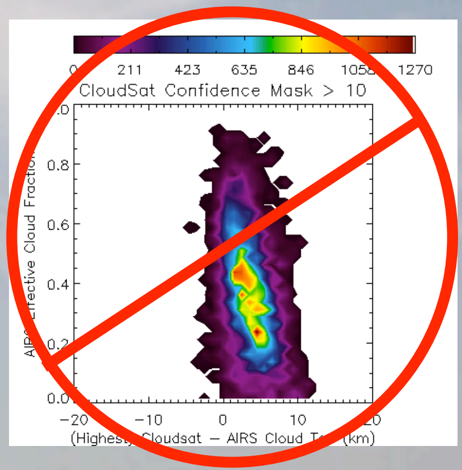
Ci



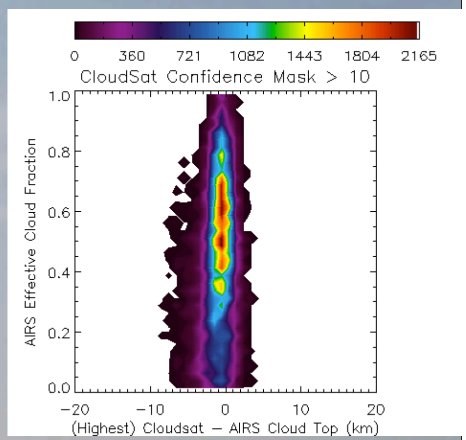
Cu



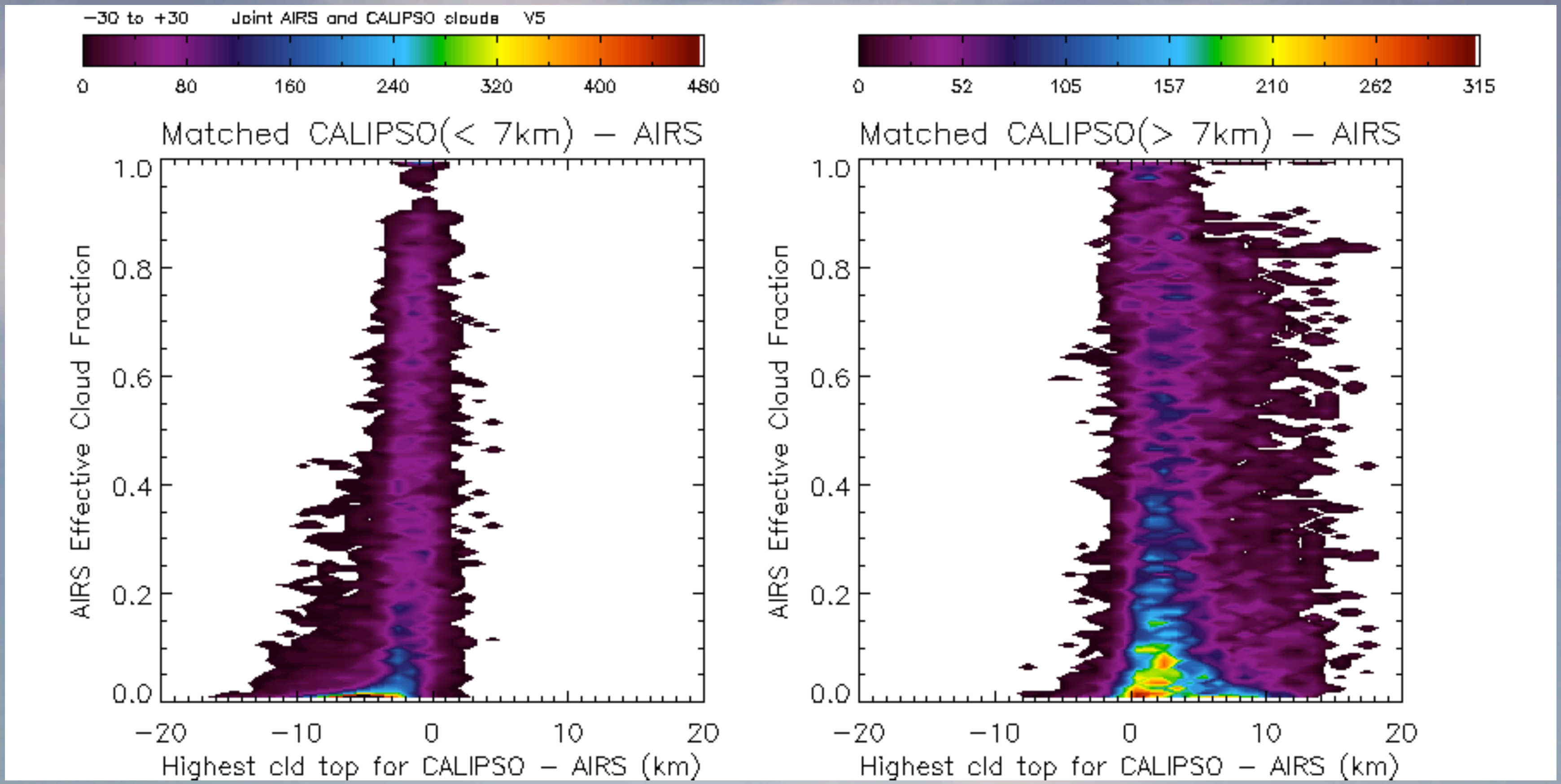
Ns



Sc

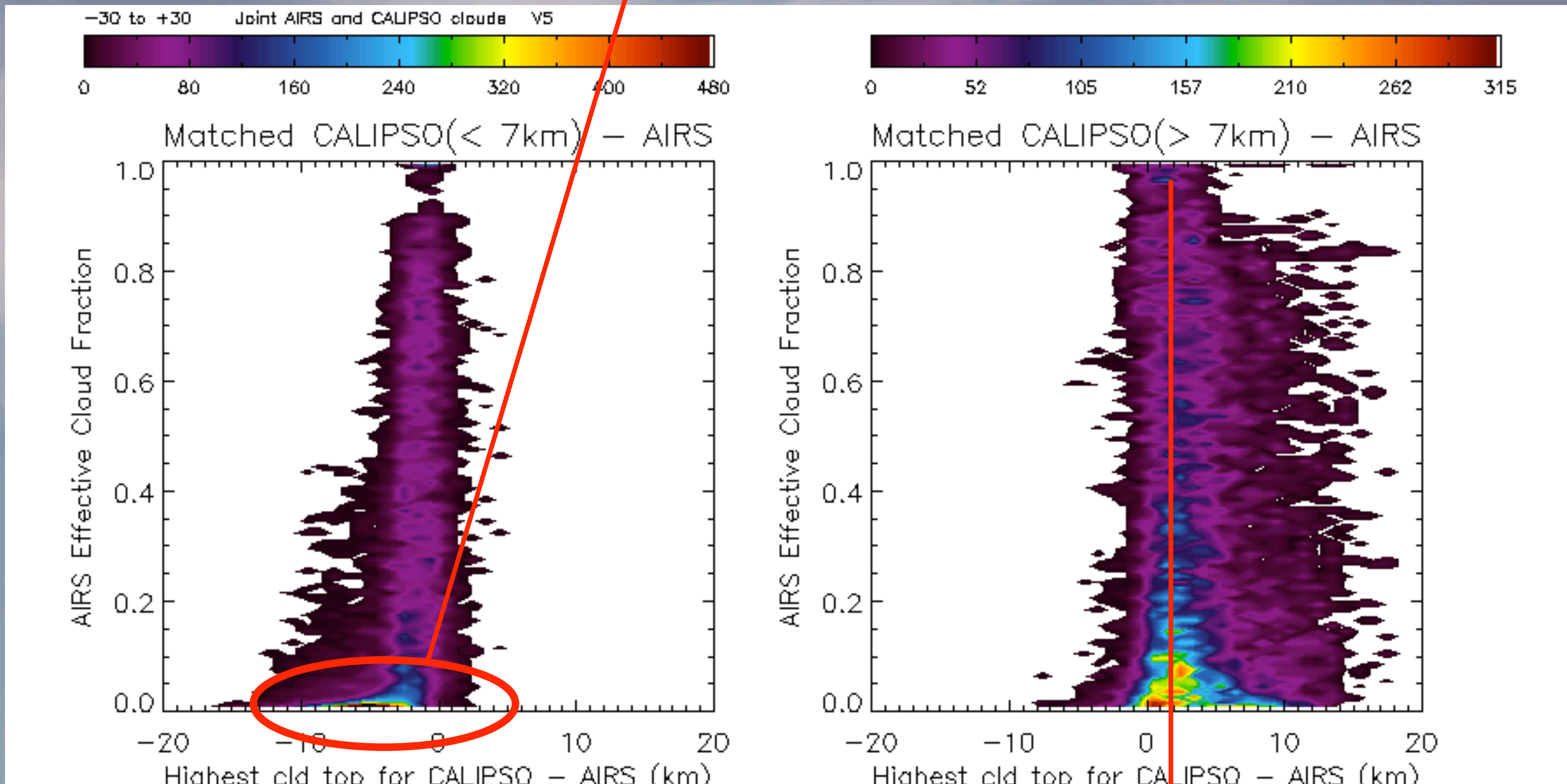


CALIPSO–AIRS (Upper) Z_{CLD}: Bias + variability



CALIPSO–AIRS (Upper) Z_{CLD}: Bias + variability

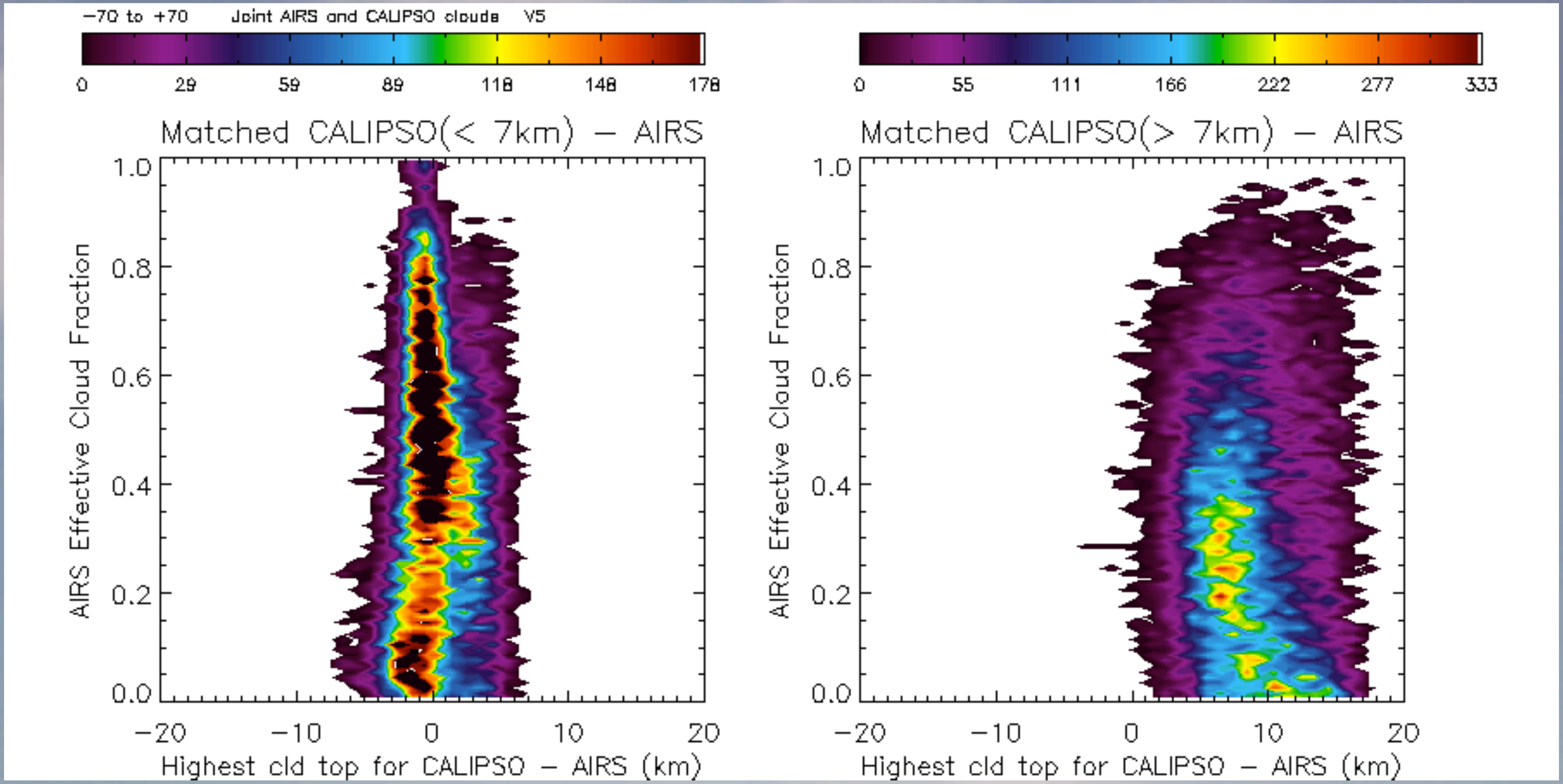
CALIPSO confirms many thin AIRS clouds spurious



CALIPSO a few km larger

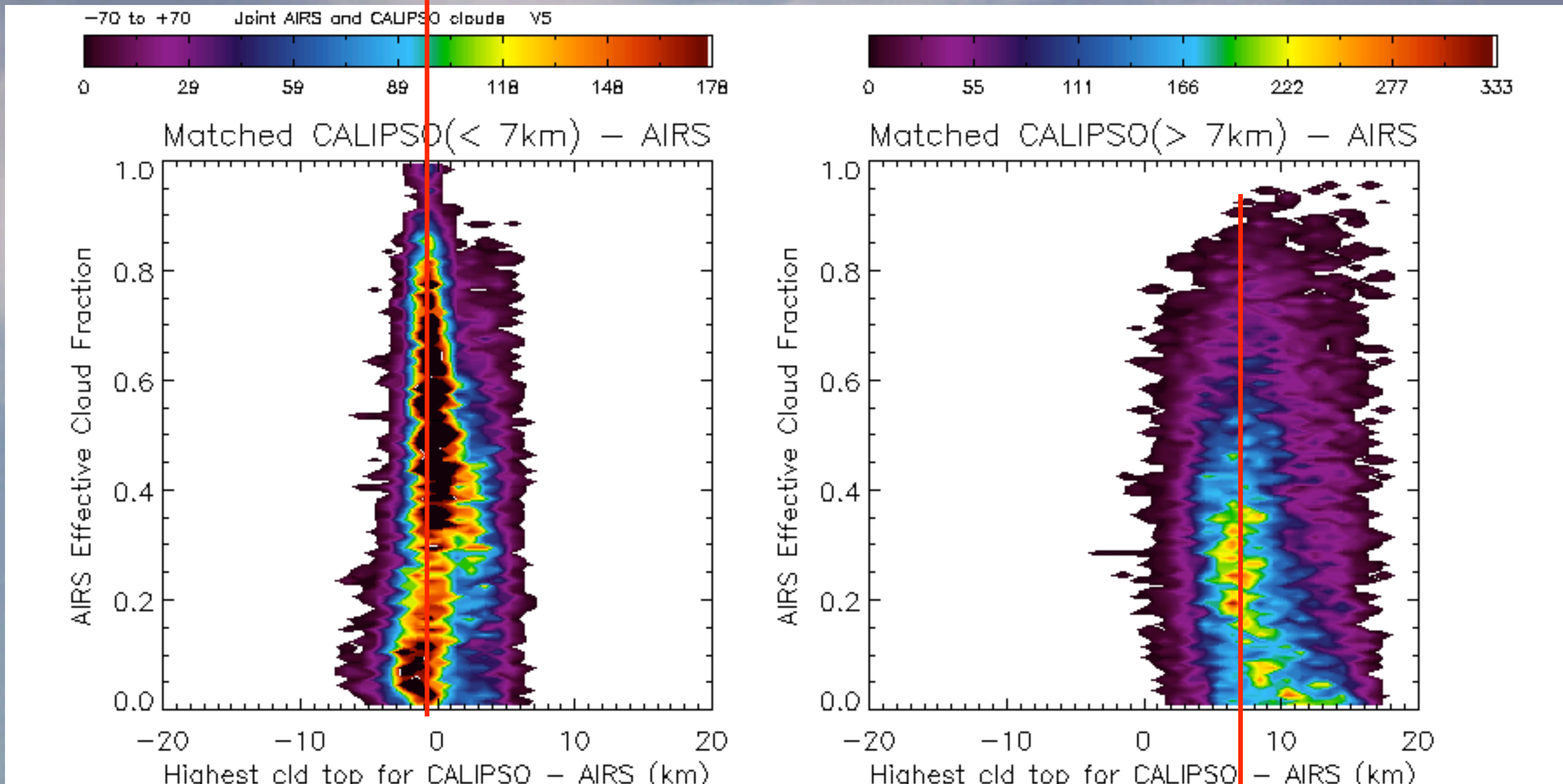
Variability largest for lowest ECF values

CALIPSO–AIRS (Lower) Z_{CLD}: Bias + variability



CALIPSO–AIRS (Lower) Z_{CLD}: Bias + variability

In presence of 2-layer AIRS scene, 2nd layer agrees very well with CALIPSO if < 7 km



2nd AIRS layer often well below top of cloud

Does not necessarily agree well with other CALIPSO layers

Summary and Conclusions

- **CloudSat and CALIPSO reveal skill in AIRS 2-layer heights**

- **Bias and variability dependent on cloud type**
  - AIRS upper layer more sensitive to Ac, As, Cb, Ci, and Ns
  - AIRS lower layer more sensitive to Cu and Sc

- **Bias slightly larger with CALIPSO than CloudSat (e.g., Ci)**
  - Expected due to known instrument sensitivities

- **Reveals some limitations in AIRS cloud fields**
  - Very thin, spurious, CALIPSO does not observe (day and night)
    - Behavior observed via other analyses
    - Treatment of CO_2 source of thin Ci frequency/trends (Hearty et al., 2006, AGU poster)
  - Lower layer often placed within opaque clouds
    - Well below height range of sensitivity in IR

- **A-train cross-platform analyses are bearing fruit!**